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Weight Loss and Nutrient Dynamics in Decomposing Woody Loblolly Pine Logging Slash

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Table 1—Predicted quantity of logging slash† by component following clearcutting of a 41-yr-old loblolly pine plantation on a good upland site in the Piedmont of South Carolina.

Component	kg/ha
Stems (15–5 cm diam)	11 251
Large branches	7 515
Medium branches	21 839
Small branches	6 349
Branch bark	13 800
Foliage	6 460
Total	67 214

† Values for stems and branches do not include bark.

Weight loss of woody components was characterized using least squares and weighted least squares estimation on an exponential decay function (Olson, 1963):

$$Q_t = Q_0 e^{-kt}$$

where Q_t = density at time t (yr), Q_0 = initial density, and k = the annual exponential (base e) decay coefficient. Based on visual inspection, we estimated that initially 80% of the slash was aerial and 20% was in contact with the ground; and after 5 years 20% was aerial and 80% was in contact with the ground. We assumed that the decay rate was constant over the range of weight-loss data and that the relative proportions of slash in the proximity-to-ground classes changed linearly with time.

Decay rates for the size classes were found after weighting data by the assumed relative proportions of slash in the two proximity-to-ground classes. However, the large size class was not separated into two position classes since no large slash occurred on the 3.5-yr-old clearcut, nor was any present aerially on the two older clearcuts. Resulting decay coefficients were applied to initial slash weights of a clearcut 41-yr-old loblolly pine stand growing on a good upland site in the South Carolina Piedmont. Slash weights (Table 1) were computed from biomass component equations for a similar 41-yr-old stand (Van Lear et al., 1984) using measured diameters of all trees on a 0.65-ha watershed. Stems to a 15-cm upper merchantable limit were removed in the harvest. The stand had a site index (SI) of 27 m at 50 yr and a BA of 38 m^2/ha; and contained 260 t/ha total biomass of which 67 t/ha was calculated to be logging slash, i.e., material above a 15-cm stem diameter. The stand had not been thinned. An overall decay rate was estimated not only by weighting relative proportions of ground-contact and aerial slash at different ages, but also by weighting relative proportions of slash in each size class. The principle of conditional error (Swindel, 1970) using an approximate (since the decay model is nonlinear in parameters) F-test was performed to detect differences between decay rates.

Least squares estimation was also used to characterize changes in nutrient concentrations with time. To model nutrient content of logging slash as it decomposes, decay rates, as applied to initial slash quantities, were multiplied by nutrient concentration equations. Therefore, quantification of nutrients in woody logging slash was a prediction based on predicted nutrient concentrations from slash of different ages applied to predicted amounts of logging slash at different ages. Since 11-yr-old material was not included in estimation of decay rates, nutrient contents were only predicted through 7 years.

RESULTS AND DISCUSSION

Weight Loss

Density of loblolly pine woody slash decreased with time (Table 2). Variability of density values increased with age reflecting the heterogeneous nature of wood decay due to varying moisture and temperature conditions and differential colonization of the slash by fungi.

Table 2—Mean density values (Mg m^{-3}) of loblolly pine woody slash by size and proximity-to-ground classes over the ccurse of decay (SE in parentheses).

	Small		Medium		Large	
Years since cutting	Ground-contact	Aerial	Ground-contact	Aerial	Ground-contact	Aerial
0	0.481 (0.006)		0.473 (0.010)		0.466 (0.018)	
0.5	0.456 (0.007)	0.454 (0.008)	0.478 (0.006)	0.488 (0.008)	0.478 (0.008)	0.457 (0.009)
1.5	0.453 (0.009)	0.458 (0.008)	0.472 (0.011)	0.486 (0.010)	0.447 (0.008)	0.471 (0.014)
3.5	0.369 (0.014)	0.440 (0.005)	0.353 (0.011)	0.413 (0.014)	–	
5.75	0.355 (0.011)	0.377 (0.013)	0.316 (0.022)	0.343 (0.016)	0.309 (0.010)	–

Branches in contact with the ground decayed at about 50% higher rate than aerial slash (Table 3), which is consistent with previous studies (Loman, 1962; Wagener and Offord, 1972). Apparently, temperature and moisture conditions are more conducive to decay when logging debris touches the ground. Also, fungal hyphae have direct access to slash contacting the ground, and thus colonization occurs faster.

Decay coefficients (k) of woody slash were 0.051, 0.079, and 0.075 for small, medium, and large size classes, respectively. Small branches decayed more slowly ($P < 0.01$) than medium and large branches, but there was no significant difference in decay rates of branches in the latter two categories. Previous slash decomposition studies found that small branches remain virtually intact several years after logging (Spaulding, 1929; Spaulding and Hansbrough, 1944; Wagener and Offord, 1972). Decay retardation in small branches is attributed to case-hardening, the early and complete drying out or seasoning of the outer portions of sapwood (Spaulding and Hansbrough, 1944). Larger woody slash is less affected by case-hardening, probably because of a smaller surface-to-volume ratio and because insulation by outer regions make temperature and moisture conditions more favorable for decay.

Decay retardation of smaller branches of slash has not been observed by all investigators. Abbott and Crossley (1982) stated that smaller pieces decay faster. They studied decomposition of *Quercus prinus* L.

Table 3—Exponential decay coefficients (k) for loblolly pine woody logging slash following clearcutting (standard errors in parentheses).†

	Wood slash		
Size	Ground-contact	Aerial	Weighted average
Small	0.058 (0.005)	0.036 (0.004)	0.051 (0.005)
Medium	0.081 (0.007)	0.057 (0.006)	0.079 (0.005)
Large‡	0.075 (0.006)§		0.075 (0.006)
Weighted average	0.068 (0.004)¶	0.045 (0.003)¶	0.072 (0.003)

† Averages for the size classes are weighted by proportion in each proximity-to-ground class, while averages for the proximity-to-ground classes are weighted by the proportion in each size class.
‡ Includes stems with diameters < 15 cm.
§ Includes ground-contact slash on all areas and aerial slash on 0.5- and 1.5-yr-old clearcuts.
¶ Excluding large size class.

composition (Cowling and Merrill, 1966), little release of these elements through mineralization would be expected in the time frame of this study. Initial losses of these nutrients during the early years of decomposition suggest that leaching occurs prior to complete microbial colonization of the woody debris. Much of this early loss may be accounted for by leaching of organic compounds, including amino acids (Tukey, 1970).

The delayed increase in content of N and P in woody logging slash following clearcutting indicates that input from external sources occurs during decomposition. Cowling and Merrill (1966) hypothesized that under conditions of soil contact, fungi can actively assimilate N directly from the soil, and that fixation of atmospheric N may increase total quantities in decaying wood. Nitrogen fixation has since been found to occur in decaying wood, although at low levels (Cornaby and Waide, 1973; Larsen et al. 1978, 1982; Harvey et al., 1979). Gosz et al. (1973) suggest increase in N content of branch litter may be a result of absorption from precipitation and moisture in the forest floor. Relatively high concentrations of nutrients on the 11-yr-old clearcut also may have resulted from throughfall inputs containing elements leached from the expanding canopy of the hardwood coppice stand (primarily water oak and sweetgum) that replaced the clearcut pine. Another possible source of N input may be from frass deposited by invertebrates colonizing the woody debris (Foster and Lang, 1982). Phosphorus may be accumulated by similar processes, excepting addition from gaseous sources.

In contrast to N and P, concentrations of K, Mg, and Ca decreased following cutting (Fig. 1). As with N and P, concentrations increased sharply on the 11-yr-old area. Initial concentrations for the various size classes generally followed the same order as for N and P, i.e., small > medium > large. Potassium concentrations decreased most rapidly over time and Ca concentrations the least rapidly. Potassium and magnesium in the small size class exhibited much larger decreases than the two larger size classes.

Contents of K, Mg, and Ca in woody logging debris were predicted to decrease gradually and level off at approximately 7 yr following harvest (Fig. 2). Potassium exhibited the largest decrease in quantity as decomposition proceeded. Potassium decreased from an initial weight of 32 kg/ha to 8 kg/ha after 7 yr. Corresponding quantities for Mg were 14 kg/ha to 6 kg/ha, and for Ca values were 41 kg/ha to 20 kg/ha.

Concentration and content patterns in decomposing woody slash for K, Mg, and Ca suggest leaching is the major process associated with these cations during decay. The order of rank in leachability of these cations is K > Mg > Ca. This order agrees well with previous investigations (Gosz et al., 1973; Whittaker et al., 1979). Calcium is generally considered the least leachable of these nutrients because of its relative importance as a structural component (Whittaker et al., 1979) and thus may be released primarily through mineralization with subsequent leaching.

Logging slash with ground contact is more quickly leached than aerial slash, presumably because the former remains wet longer following precipitation. Nutrient concentrations in ground-contact slash, when averaged for all sizes on the 0.5-yr-old clearcut, were 88, 72, 76, and 95% of concentrations in aerial slash for N, P, K, and Mg, respectively. However, ground-contact slash showed higher concentrations for Ca. This pattern was most evident in the smaller diameter woody debris, probably because a higher proportion of individual volume is affected.

CONCLUSIONS

Nutrients contained in logging slash are made available for regrowth through net mineralization and leaching. Except for small initial leaching losses, N and P in woody logging slash are not released for tree nutrition until after the regeneration period. Release of N through mineralization is not thought to occur until the C/N ratio of the substrate is lowered to a critical value, generally considered to be between 20:1 and 30:1 (Alexander, 1977, p. 243). However, Berg and Ekbohmo (1983) demonstrated that the critical ratio at which release of N begins may vary among sites. Working with *Pinus sylvestris* L. needle litter, they found that this C/N ratio was 109 in a mature forest and 63 in a clearcut. Nitrogen and phosphorus quantities in logging debris were predicted to increase after the initial period of decomposition, suggesting that woody slash serves as a sink for these nutrients as decomposition occurs. As the C/element ratio further declines as decomposition proceeds, nutrients in the logging slash will be released for uptake by the stand. Covington (1981) has suggested that decomposition of the forest floor is important in supplying nutrients during the regeneration phase and that slash decomposition is important nutritionally to the stand later in the rotation.

Not all nutrients will be held in woody slash for as long a period of time. A large proportion of K (76%), Mg (56%), and Ca (47%) in the logging slash is released during the first 5 to 6 yr following harvest.

During the regeneration period, regrowth is often inadequate to efficiently recycle nutrients. Logging slash left on the site helps to conserve nutrients following harvest. Acting as a slow-release fertilizer, decomposing logging slash releases nutrients gradually at different rates depending upon the nutrient. The nutritional value of the slash would be most important after the regeneration period.

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